Effect of Vapor Heat on the Export Quality of Fresh Tomato (*Solanum lycopersicum* L.)

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Abstract

Postharvest heat treatments have been used for fruit disinfestation of insects, disease control, and modification of reactions of the fruits to physiological stress produced by postharvest treatments with low temperatures. The present study evaluated the effect of the application of vapor heat at 46°C on the quality of the 'Long Life' variety tomato at two maturity stages and two fruit sizes; fruit sizes chosen were: a) between 280-450 g, and b) between 200 and 279.9 g; the evaluated maturity grades were breaker stage and green stage. The measured parameters were the quantitative: weight loss, firmness, soluble solids, pH, and citric acid and qualitative ones: external appearance, internal appearance, and flavor. The treatment with vapor heat did not produce satisfactory results in respect to the quality of the tomato fruits. Some of the quantitative parameters revealed statistical differences when comparing the treated fruits with the control, but not all of these fruits were rejected in the sensory evaluation. The main parameters of rejection were the qualitative variables and the external appearance was the major factor of non-acceptance. The results presented in this investigation showed that the 'Long Life' variety of tomato grown in Colombia did not tolerate the vapor heat treatment applied.

INTRODUCTION

The tomato fruits are hosts of quarantine pests, such as the Mediterranean fruit fly, *Ceratitis capitata* (Wied.) and the presence of quarantine pests becomes a barrier to export fresh produce to other countries. The temperature is one of the major factors that limit the survival and reproduction of insects (Hallman and Delinger, 1998), in this way the heat treatments on post-harvest fruit have been used for insect disinfestation (Chaparro et al., 2005). The quarantine treatment of vapor heat uses hot air saturated with water vapor to raise the temperature of perishable foods (fruits and vegetables) at a given temperature for a specific period of time to ensure that all pests are eliminated (EPA, 2006).

The two objectives of the quarantine treatment that may be difficult to harmonize are: 1) to control pests of product, and 2) not to damage the product significantly with the treatment (Hallman, 1991); for this reason, even if the treatment is effective for mitigation of the risks of quarantine pests, it is essential to assess the potential impact on the quality of fresh fruit to export. The present study was aimed at determining the effects of vapor heat treatment T106-e on the quality of fresh tomato (*Solanum lycopersicum* L.) variety 'Long Life' at two stages of maturity and fruit sizes.

MATERIALS AND METHODS

This study was conducted at the facilities of the Laboratory of Quarantine Treatments of the Colombian Agricultural Institute (ICA-LTC) under the agreement of the project Center of Excellence in Pest Mitigation (CEMIP) circumscribed within the Center for Phytosanitary Excellence (CEF, Agreement ICA-APHIS-IICA-USAID).

Plant Material

Sixty five kilograms of fresh tomatoes, variety 'Long Life', were used to evaluate the effect of vapor heat treatment on the physical and chemical characteristics of tomatoes with export quality. The fruits were classified according to maturity and weight. Through visual assessment of maturity using skin color we determined two degrees of maturity: 1) green: fruits showing green color, from dark to light, breaking to yellow, pink or red on no more than 10% of the area, and 2) breaker: between 10 and 40% of the surface of the fruit shows a definite change from green to yellow, pink or red, or a mixture of them. Tomatoes were classified by weight as large size (280-451 g) and medium size (200-279.9 g). Experimental fruits were grouped as large green, large breaker, medium green, and medium breaker.

Treatment

The tomato fruits were washed and disinfected with an aqueous solution of 2.5 g L of sodium benzoate to prevent the occurrence of harmful agents. The fruits are distributed in trays within a chamber of vapor heat (VHT) brand Sanshű Differential Pressure Type Model EHK D-1000, which was scheduled to meet the requirements of the treatment T106-e consisted of preheating during 4 h to obtain 46ºC in the middle of the fruit and hold this temperature for 20 min. (USDA, 2008). Twelve temperature sensors were placed inside the experimental fruit. A cold shower for 30 min. was programmed once the treatment was finished. Treated fruits were stored at 10ºC with 85% R.H. and all their characteristics were evaluated at 0, 5, 10, 15 and 20 days after the treatment. Seven fruits for each experimental group were taken at random for these evaluations.

Parameters Evaluated

Fresh weight, firmness determined using digital penetrometer Fujiwara brand KMH-51, soluble solids (°Brix), pH, titratable acidity, flavor, internal and external appearance. Flavor and appearance (internal and external) were the qualitative evaluations through an organoleptic test, in which a person evaluated presence of microorganisms, color, smell, spots, rots, dehydration or any other damage showed. This was measured by a qualified evaluation panel using procedures of sensory evaluation based on the criteria for acceptance or rejection considering the intensity of damage. The same person performed these qualitative measures and the fruits were classified as normal (accepted) or abnormal (rejected).

Experimental design for data analysis used a completely randomized design (CRD). The averages were compared with Tukey test with a level of significance of P=0.05; analysis of variance was conducted by day of evaluation and grouping by size, maturity and treatment.

RESULTS AND DISCUSSION

Weight Loss

Both the large greens fruits and middle breaker fruits showed significant differences when compared with untreated fruits. Weight loss is directly proportional to the time of evaluation (Table 1) and attributable, in particular, to transpiration and respiration, which is expressed as moisture loss (Kays, 1997). In the same way, these differences can be attributed to the application of high temperatures as they produce an increase in transpiration and, thus, a decrease in weight of the fruits (Gallo, 1996; Klein and Lurie, 1990). These authors argue that the rate of respiration in ripening fruit is initially increased by exposure to high temperatures. In general, green fruits had a weight loss rate greater than one of the breaker fruits (Table 1).

Firmness

In all cases, control fruits were firmer than treated fruits (Table 2), which is different from the statements by Kays (1997) and Ketsa et al. (2000), who found that high temperatures result in firmer fruits. However, the change in the firmness of treated fruits could be attributed to the heat that accelerates the processes of respiration and transpiration and, in this way, the degradation of the polysaccharides (Reina et al., 1998) rendering softer fruits. In addition, water loss during this process will affect the turgidity of cells (Paull and Jung Chen, 2000; Vicente, 2004). Statistical differences were shown when treated and control fruits were compared for all groups of fruits in some of the evaluations. Being treated breaker fruit (large and medium) differed from those not treated that were more frequent during the evaluations (Table 2). Green fruits were less affected by the treatment than fruits at the breaker stage. Green fruits of all evaluations showed a higher firmness than compared to the breaker fruits. Softening of the fruits is part of the maturation process, which causes enzymatic degradation (Tucker and Grierson, 1987) Is clear that the breaker fruits have gone through a longer period of enzymatic degradation compared with green fruits.

pH

The treated fruits generally showed higher pH values than control fruits (Table 3). Statistical differences in pH were found for all groups when treated fruits were compared to untreated fruits, especially in green fruits.

There is a tendency to a higher pH in treated fruits (Table 3). The higher stress due to treatment resulted in an increase of energy consumption, which, in turn, might produce a higher pH (Paull and Jung Chen, 2000). Lower pH was found in breaker fruits in comparison to green fruits. There were strong changes in pH of the green fruits compared with the changes in breaker fruits. Gallo (1996) reported that increased degradation of chlorophyll caused the change in color during the maturation process, which, in part, is due to a change of pH.

Soluble Solids

The trend of variable Brix degrees in the two evaluated maturity grades was similar. The overall trend is slightly increasing with some fluctuations (Table 4), which could be explained because tomato is a climacteric fruit and during the process of maturation the carbohydrates suffer biochemical changes among which the hydrolysis of polysaccharides exerts a significant contribution on the increase in sugar content (Reina et al., 1998). Statistical differences were observed in large fruits at the breaker stage and large and medium fruits in the green stage of the first two evaluations (Table 4). There were no statistical differences among treated and untreated fruits at the end of the storage. This is consistent with studies of McDonald et al. (1999) who found no effect on soluble solids after the application of heat treatments in tomato.

Acidity

In both groups, green and breakers, there was an inverse relationship between citric acid and storage time (Table 5). It might be explained because, as the maturity time increases, the organic acids are used for respiration decreasing their content in the fruit. Statistical differences were found in some evaluations among all groups of fruits (Table 5). The treated fruits showed lower averages in acidity as compared with control fruits. This agrees with other studies in tomato and various fruits (Vicente, 2004), in which such changes may be due to increased respiration activity during the heat treatment (Yahia et al., 2001).

Flavor, External and Internal Appearance

In both treated and control fruits of the large green group, there was a rejection of fruits from the 5th day of evaluation due to external appearance. In respect to the internal appearance and flavor, there was some degree of rejection in treated fruits compared to control fruits (Table 6), in which there was no any rejection. In the large breaker group, there was a high rejection (86%) due to external appearance starting on day 5, while in the control group rejection started on day 14 revealing a lower percentage (19%) (Table 6). In the treated green medium group, there was rejection due to external appearance of fruits on day 5, while in the control fruits rejection started on day 10. Regarding the same green medium group, the control fruits did not have any rejection due to flavor and internal appearance, while treated fruits showed a high rejection rates from day 10. Finally, in the group of medium breakers fruits rejection due to external appearance was shown on day 5, while rejection of fruits in the control began on day 14 (Table 6). In control fruits, there were no rejection due to internal appearance, while the treated fruits showed rejection of fruits from the 10th day on. Related to flavor there was a 29% rejection in control fruits on day 20, while in treated fruits there was a high rejection starting on day 10 (Table 6).

The external appearance is presented as the main factor for rejection. Morris and Brady (2005) established that the effects of high temperatures (35°C) on fresh fruits affected the process of a loss of pigments, which produce a transparent or aqueous aspect on the fruit and a general disruption of the membrane and cell structure.

In general, observing the behavior of sensory or qualitative parameters, there are high percentages of rejection in all sizes and stages of maturity. Thus, this vapor heat treatment applied for tomato fruits variety 'Long Life' would not be recommended for farmers and traders.

CONCLUSIONS

- The quarantine treatment with vapor heat at 46°C induces or accelerates some problems in the quality of the fruits that are perceived in the sensory evaluation as faults of appearance and are one of the principal reasons of rejection.
- The quarantine treatment with vapor heat at 46°C causes injuries in the tissues of tomato fruits, these injuries develop and become evident during the storage and affect fruit appearance.
- The results of this research in fruits of tomato 'Long Life' suggest that the treatment with vapor heat to 46°C is not applicable to fruits of this variety and origin because of the injuries that it causes in the fruits, therefore, we recommend evaluating other experimental conditions and other treatments.

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Tables

Table 1. Weight loss (%) of tomato fruits after vapor heat treatment (46°C).

Day	Green fruits (large)		Green fruits (medium)		Breaker fruits (large)		Breaker fruits (medium)	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
0	1.32 a	0.81 b**	1.60 a	1.14 a	1.14 a	0.89 a	1.27 a	0.92 a
5	2.69 a	4.06 b	3.06 a	3.71 a	3.18 a	2.84 a	3.14 a	4.05 a
10	5.79 a	4.75 a	7.23 a	5.59 a	4.20 a	6.86 a	4.53 a	7.02 b
15	11.26 a	17.06 a	11.59 a	8.56 a	5.37 a	6.66 a	6.24 a	9.21 a
20	11.25 a	8.56 a	9.48 a	12.63 a	7.42 a	12.63 a	8.20 a	10.19 a

Averages with different letters are significantly different according to Tukey test ($P \leq 0.05$), letters with ** are highly significant different ($P \leq 0.01$).

Table 2. Firmness (kg cm^{-2}) of tomato fruits after vapor heat treatment (46°C).

Day	Green fruits (large)		Green fruits (medium)		Breaker fruits (large)		Breaker fruits (medium)	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
0	0.828 a	0.724 b**	0.796 a	0.75 9a	0.749 a	0.682 b	0.762 a	0.659 b**
5	0.737 a	0.718 a	0.730 a	0.710 a	0.674 a	0.593 b	0.712 a	0.559 b**
10	0.747 a	0.716 b	0.753 a	0.681 b	0.641 a	0.637 a	0.708 a	0.566 b**
15	0.749 a	0.720 a	0.696 a	0.690 a	0.689 a	0.601 b**	0.712 a	0.539 b**
20	0.704 a	0.674 a	0.680 a	0.643 a	0.624 a	0.524 b	0.596 a	0.570 a

Averages with different letters are significantly different according to Tukey test ($P \leq 0.05$), letters with ** are highly significant different ($P \leq 0.01$).

Table 3. pH of tomato fruits after vapor heat treatment (46°C).

Day	Green fruits (large)		Green fruits (medium)		Breaker fruits (large)		Breaker fruits (medium)	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
0	3.89 a	3.83 a	3.70 a	3.84 a	3.79 a	3.83 a	3.80 a	3.89 a
5	3.76 a	4.01 b**	3.81 a	4.09 b**	3.83 a	3.97 b**	3.90 a	4.00 b
10	3.89 a	4.11 b**	3.93 a	4.04 b	3.96 a	4.07 a	4.00 a	3.90 b
15	4.17 a	3.93 b**	3.86 a	4.13 b**	3.93 a	4.04 a	3.93 a	3.99 a
20	4.20 a	4.17 a	4.05 a	4.19 b**	4.09 a	4.03 a	3.95 a	4.11 a

Averages with different letters are significantly different according to Tukey test ($P < 0.05$), letters with ** are highly significant different ($P \leq 0.01$).

Table 4. Soluble solids (°Brix) of tomato fruits after vapor heat treatment (46°C).

Day	Green fruits (large)		Green fruits (medium)		Breaker fruits (large)		Breaker fruits (medium)	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
0	4.70 a	4.87 a	4.24 a	4.94 b	4.34 a	4.84 b**	4.47 a	4.74 a
5	5.20 a	4.91 b	5.09 a	4.87 b	4.94 a	4.69 a	4.61 a	4.47 a
10	5.31 a	4.69 a	5.36 a	5.39 a	4.70 a	5.13 a	5.06 a	4.96 a
15	5.40 a	5.00 a	5.10 a	5.17 a	4.73 a	4.51 a	4.97 a	5.23 a
20	5.09 a	4.79 a	5.16 a	5.13 a	4.64 a	4.97 a	4.91 a	4.96 a

Averages with different letters are significantly different according to Tukey test ($P \leq 0.05$), letters with ** are highly significant different ($P \leq 0.01$).

Table 5. Titratable acidity (%) of tomato fruits after vapor heat treatment (46°C).

Day	Green fruits (large)		Green fruits (medium)		Breaker fruits (large)		Breaker fruits (medium)	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
0	0.66 a	1.06 b**	0.75 a	0.94 a	1.03 a	0.70 a	0.84 a	0.92 a
5	0.78 a	0.48 b*	1.02 a	0.63 b	0.98 a	0.52 b	0.78 a	0.47 b**
10	0.84 a	0.69 a	0.80 a	0.70 a	0.68 a	0.62 a	0.80 a	0.55 b
15	0.72 a	0.49 b	0.92 a	0.65 b**	0.78 a	0.79 a	0.65 a	0.57 a
20	0.62 a	0.39 b**	0.63 a	0.37 b**	0.49 a	0.46 a	0.35 a	0.62 b

Averages with different letters are significantly different according to Tukey test ($P \leq 0.05$), letters with ** are highly significant different ($P \leq 0.01$).

Table 6. Percentage of rejection due to flavor, external and internal appearance of tomato fruits of large sizes after vapor heat treatment (Ext.= External, Int.= Internal).

Day	Green stage (large)						Breaker stage (large)					
	Control			Treatment			Control			Treatment		
	Flavor	Appearance		Flavor	Appearance		Flavor	Appearance		Flavor	Appearance	
		Ext.	Int.		Ext.	Int.		Ext.	Int.		Ext.	Int.
0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	14	0	0	29	0	0	0	0	0	86	0
10	0	43	0	0	14	43	0	0	0	57	71	29
14	0	71	0	14	71	43	0	19	0	14	43	0
20	0	71	0	29	43	29	0	14	0	14	71	29

Table 7. Percentage of rejection due to flavor, external and internal appearance of tomato fruits of middle sizes after vapor heat treatment (Ext.= External, Int.= Internal).

Day	Green stage (middle)						Breaker stage (middle)					
	Control			Treatment			Control			Treatment		
	Flavor	Appearance		Flavor	Appearance		Flavor	Appearance		Flavor	Appearance	
		Ext.	Int.		Ext.	Int.		Ext.	Int.		Ext.	Int.
0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	43	0	0	0	0	0	43	0
10	0	71	0	86	86	57	0	0	0	71	100	57
14	0	14	0	29	71	29	0	14	0	14	71	43
20	0	57	0	43	100	57	29	57	0	57	57	57